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THE EFFECT OF NITROGEN, PHOSPHORUS, BORON AND MAGNESIUM FERTILISER IN CONJUNCTION WITH WEED CONTROL ON THE GROWTH AND NUTRITION OF A POLE STAGE STAND AT MAMAKU FOREST IN THE CENTRAL NORTH ISLAND - RESULTS AFTER FOUR YEARS

By

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The effect of nitrogen, phosphorus, boron and magnesium fertiliser in conjunction with weed control on the growth and nutrition of a pole stage stand at Mamaku Forest, in the Central North Island. The results after four years.

by

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ABSTRACT

On P deficient Mangowera/Otanewainuku soils of the Mamaku Ranges, radiata pine responded dramatically to both weed control and the application of phosphate fertiliser as North Carolina Reactive Rock at 50 kg P/ha. After 4 years radiata pine productivity was improved by 52% with both weed control and P fertiliser. Growth responses to N and B were non existent, but there were indications that Mg fertiliser may have a role in improving productivity, particularly in the absence of weed control.

INTRODUCTION

On the Mamaku Plateau radiata pine was introduced as a commercial production crop in the early 1970's. The then accepted practice of site preparation by V-blading removed considerable quantities of top-soil which in itself was P deficient, exposing sub-soil of even lower fertility. The low P fertility of the top-soil can be ascribed to podzolization under the previous native podocarp forest.

MATERIALS AND METHODS

The site

The native vegetation is Podocarp broadleaf forest scrub and the average rainfall is about 2000 mm/year. In the late 1970's and early 1980's the sites were prepared for radiata pine by burning and blading off the debris into windrows. This blading operation removed considerable amounts of topsoil into the windrows.

The soils

The soils are classified as primary podzolic soils in the Kaharoa suite (NZ Soil Bureau, 1954). The two dominating soil types in the area held by Tasman Forestry Ltd are Mangowera sand, derived from Kaharoa ash, and Otanewainuku sand and sandy silt, derived from rhyolite and rhyolitic ash. Total P reserves are low for the Mangowera soil: in the top 8 cm the reserves are 0.007%; and between 9 and 11 cm total P is 0.003%. For the Otanewainuku soils, total P reserves are marginally higher at 0.011% to a depth of 17 cm.

The current radiata pine crop

Foliage samples from the neighbouring Galaxy Rd and Otanewainuku area showed the following nutrient concentrations:

	Major nutrients in %; minor nutrients in ppm								
	N	P	K	Ca	Mg	Zn	Mn	B	Cu
Site A	1.28	.0.07-.09	0.73	0.13	.09	37-41	233-284	7-9	25-27
Site B	ND	0.01	ND	ND	ND	ND	ND	ND	ND

ND = not determined

These analyses show that P is acutely deficient and that N is marginal for growth (Will, 1985). The B levels between 7 and 9 µg/g are cause for concern and the Mg levels are marginal.

The crop will certainly respond to the addition of P, and additional gains are likely with added N. Boron should be added to raise foliar B levels to greater than 11 - 12 ppm and the need for Mg cannot be predicted. With the application of N and P, the soil Mg reserves may not be able to sustain foliar Mg levels.

Experimental design

The basic trial examines N, P, B, and weed control as a 2^4 factorial, and "step out" plots examine the need for fertiliser Mg.

The treatment schedule is:

N (2 levels at 0 and 200 kg N/ha) by P (2 levels at 0 and 100 kg P/ha) by B (2 levels at 0 and 8 kg B/ha) by weed control (yes/no). The trial was replicated twice.

With this design it was thought extremely unlikely that the third order interaction (N*P*B*WC) would be of significance. It was therefore decided to amend the complete factorial design shown in Table 1 to that of a fractional factorial (Table 2).

Table 1. ANOVA for experimental design

Source of variation	Degrees of freedom
Total	31
Blocks	1
N	1
P	1
B	1
WC	1
N*P	1
N*B	1
N*WC	1
P*B	1
P*WC	1
N*P*B	1
N*P*WC	1
N*B*WC	1
P*B*WC	1
*N*P*B*WC*	1
error	15

Each replicate was divided into two blocks to reduce site variability, with the removal of the third order interaction term (N*P*B*WC). The loss of this interaction term will be more than compensated for by the increased precision. The ANOVA for this field layout is shown in Table 2.

Table 2. ANOVA for field experiment (modified)

Source of variation	Degrees of freedom
Total	31
Blocks	3
N	1
P	1
B	1
WC	1
N*P	1
N*B	1
N*WC	1
P*B	1
P*WC	1
N*P*B	1
N*P*WC	1
N*B*WC	1
P*B*WC	1
error	14

Layout of the experimental plots

Each of the two replications was divided into two incomplete blocks of 16 plots each. The measurement plots are 12 m x 18 m, with a 4 m similarly treated surround (0.035 ha total plot area).

Testing of Mg and a lower rate of P

Additional plots (2 per replicate) were set up (with and without weed control) to test Mg in the presence of N, P and B. These plots were placed adjacent to their counterparts without Mg. Similarly for P at half the rate (50 kg P/ha) in the main experiment. These plots were placed adjacent to their counterparts at the full rate of P.

Trial establishment

The trial was established over the winter and spring of 1989 in a seven year-old stand of radiata pine in Compartment 3469/1.

The following fertiliser prescriptions were used:

- Nitrogen as urea at 435 kg /ha to yield 200 kg N/ha;
- Phosphorus as North Carolina phosphate rock to yield 100 kg P/ha;
- Boron as ulexite at 60 kg/ha to yield 8 kg B/ha, and
- Magnesium as calcined magnesite (medium ground) to yield 100 kg Mg/ha.

The required number of plot trees to provide 600 - 625 sph were selected and pruned to 2.5 m, and the remaining stems (about 1000 sph) were thinned to waste.

Within the weed control plots the understorey of hardwood shrubs, bush lawyer, ghania and native toetoe were cleared with a chainsaw. Vegetation regrowth is sprayed when required with "Roundup".

Measurements

The trees were measured at time of fertilising, and annually thereafter. All diameters at breast height (DBH), and total heights were processed through the NZFRI Permanent Sample Plot System (PSP). Standard foliage samples were collected from every plot during late summer, and annually thereafter. Statistical analyses of the growth and nutrition data were made using SAS. The initial growth measurements were used as the covariate.

RESULTS

(i) Tree growth

The ANOVA table (Table 3) below shows that:

- the removal of weeds has had a major effect on growth;
- there are highly significant differences between the "NPB", "N-half P-B", and the "NPBMg" treatments,
- phosphorus fertilising has had a major and sustained effect on yield;
- boron fertilising had no effect on yield.

Table 3. ANOVA for the treatment effects on growth

		Probability (italics indicates significance at P= or < 0.05)			
Source of Var	**D.f**	**1990**	**1991**	**1992**	**1993**
Covariate	1				
Weeds	1	*0.008*	<0.001	*<0.001*	*<.001*
All trts	2	*0.008*	*0.002*	*0.007*	*0.010*
Weeds*all trts	2	0.880	0.973	0.937	0.845
Nitrogen	1	0.449	0.677	0.624	0.491
Phosphorus	1	*0.003*	*<0.001*	*<.001*	*<.001*
Boron	1	0.773	0.735	0.785	0.672
Weeds*N	1	0.375	0.802	0.624	0.943
Weeds*P	1	0.872	0.841	0.876	0.801
N*P	1	0.539	0.187	0.160	0.217
Weeds*B	1	0.065	0.362	0.630	0.670
N*B	1	0.695	0.320	0.557	0.459
P*B	1	0.297	0.434	0.493	0.480
Weeds*N*P	1	0.986	0.773	0.530	0.554
Weeds*N*B	1	0.911	0.847	0.855	0.869
Weeds*P*B	1	0.602	0.427	0.608	0.709
N*P*B	1	0.231	0.937	0.803	0.875
Covariate	1	*<0.001*	*<0.001*	*<.001*	*<.001*
Residual	19				
Total	39				

The response data after 4 years is shown in Figure 1, and compares the effects of weed control alone (no nutrients) with P, N and Mg (for Mg the comparison is only with added N, P, and B). The results show:

- that the removal of weeds improved productivity by 19.1 m3/ha (24%)

- The addition of P alone has had the major effect on growth, and the gains were similar with either 100 or 50 kg P/ha. Nitrogen additions did not improve growth. With weeds present the gains to P fertiliser were about 12 m3/ha (18%) over the unfertilised trees. Where the weeds had been removed the gains were about 35 m3/ha (50%) over the unfertilised non weeded trees.
- In combination with P fertiliser, the addition of Mg to non weeded trees increased productivity by a further 12 m3/ha, or about 15% ; however, with control of weeds the difference in productivity reduced to about 6 m3/ha, or about 6%.
- that the addition of N alone depressed growth by 5 m3/ha (7%) in the presence of weeds and 10.3 m3/ha (12%) in the absence of weeds. These depressions in growth are a trend only, and not statistically significant.

The effect of weed control is not unexpected: weed removal decreases competition with radiata pine for nutrients; where "available" soil P is low, the addition of N will inhibit P uptake (and hence growth). The lack of a response to N in combination with P fertiliser indicates that soil N fertility is not limiting.

<u>(ii) Tree nutrition</u>

The ANOVA (Table 4) below follows the pattern of significance for phosphorus (years 1990 - 1993), and summarises the effects of Mg, B and N fertilising on foliar levels for 1993 (4 years after fertilising)..

Table 4. ANOVA for the treatment effects on nutrition

Source of Var	D.f	Probability (italics indicates significance at P= or < 0.05)					
		P	P	P	Mg	B	N
		1990	1991	1993	1993	1993	1993
Covariate	1						
Weeds	1	0.700	0.116	*0.012*	0.631	*0.012*	0.111
All trts	2	0.293	*0.017*	*<0.001*	0.168	*0.069*	0.599
Weeds*all trts	2	0.755	0.770	0.882	0.984	*0.071*	0.521
Nitrogen	1	0.162	*0.023*	0.101	0.695	0.422	0.558
Phosphorus	1	*<0.001*	*<0.001*	*<0.001*	0.124	0.546	*0.027*
Boron	1	0.963	0.711	0.979	0.411	*0.023*	0.688
Weeds*N	1	0.889	0.648	0.538	0.760	0.318	0.688
Weeds*P	1	0.727	0.273	0.591	0.461	0.233	0.424
N*P	1	*0.055*	0.039	0.702	0.380	0.233	0.757
Weeds*B	1	0.991	0.256	0.082	0.225	0.840	0.600
N*B	1	0.418	0.155	0.893	0.534	0.318	0.925
P*B	1	0.406	0.266	0.707	0.612	0.117	0.498
Weeds*N*P	1	0.511	0.673	0.205	0.717	0.318	0.224
Weeds*N*B	1	0.156	0.207	0.149	0.592	1.000	0.213
Weeds*P*B	1	0.539	0.698	*0.006*	0.461	0.318	0.460
N*P*B	1	0.762	0.938	0.393	0.395	0.840	0.327
Covariate	1						
Residual	19						
Total	39						

Fertilising with both the 50 and 100 kg P/ha rates achieved foliar P levels in excess (at 0.12% and 0.13%) of the critical level of 0.11% after one year (Figure 2). Where N was omitted from the nutrient mix foliar P concentrations were high at 0.17%. After 4 years foliar P concentrations (Figure 3) had either been maintained (at 50 kg P/ha) or increased (at 100 kg P/ha). The presence of Mg fertiliser appears to have slightly (but not significantly) increased foliar P concentrations at both 1 and 4 years following applications.

From the first to the third year after P fertilising, weed competition for P was not affecting tree P nutrition. By 4 years after fertilising weed competition was significantly affecting foliar P concentrations: trees without weed competition were at 0.15% P; those competing with weeds were at 0.14%. Therefore, even at the lower rate of P application, weed competition was not sufficient to decrease "available" P levels to below the threshold level of 0.11%.

Magnesium fertiliser did not significantly change foliar Mg concentrations after 4 years. With increased growth through P applications, Mg supply to the trees was not decreased.

Applying ulexite fertiliser raised radiata foliar B concentrations from 13.8 ppm (no fertiliser) to 15.9 ppm (P0.023). The effect of weed competition was to slightly decrease radiata pine foliar B concentrations from 14 ppm (weeds present) to 16 ppm (weeds removed). The interaction between a contrast of NPB, NPBMg and NPBHalfP and weed control is shown in Figure 4. In the absence of weed competition it can be argued that radiata roots have "free" access to the applied nutrients. Where there is competition for the applied nutrients between weeds and radiata, and with weeds having a significant impact of Mg availability (Payn, 1991) the indication is that Mg nutrition of radiata in the presence of weeds is having a significant impact on B uptake ie magnesium is mediating boron uptake physiology.

The significant main effect of P on N nutrition was to reduce foliar N concentrations from 1.4% (no P fertiliser) to 1.3%.

DISCUSSION

The trial raises a number of interesting points:

- the crop's N nutrition at 1.4% was deemed to be marginal (Will, 1985), but there was no response to added N.
- the crop's P nutrition has been raised to 0.13% with the application of 50 kg P/ha. This is significantly above the critical level of 0.11%. Monitoring the longer term changes (declines) in P nutrition over time will show the

extent to which 50 kg P/ha is adequate. It may be that a lower rate would suffice.

- the gains in productivity when Mg is applied (but only in the presence of weeds) is intriguing. It is unfortunate that the understanding of the condition of Upper Mid-Crown Yellowing (UMCY) was in it's infancy when the Mamaku trial was designed. A full factorial in N, P, B and Mg, or alternatively, in N, P and Mg would have clarified the unusual result obtained.

CONCLUSIONS

On very P deficient Mamaku soils controlling the weeds on the site improved the productivity of a 7 year-old radiata pine crop over a 4 year period by 30% (from 69 m3/ha to 90 m3/ha). Without weed control, an application of 50 kg P/ha as North Carolina reactive rock achieved an increase of 11% (81 m3/ha); where weed control and P fertilising were combined the gains were 52% (105 m3/ha). There were indications that an application of Mg in the fertiliser mix in the absence of weed control further improved growth, although this result was not statistically significant. Nitrogen fertilising alone depressed growth and B fertilising had no effect on growth.

ACKNOWLEDGMENTS

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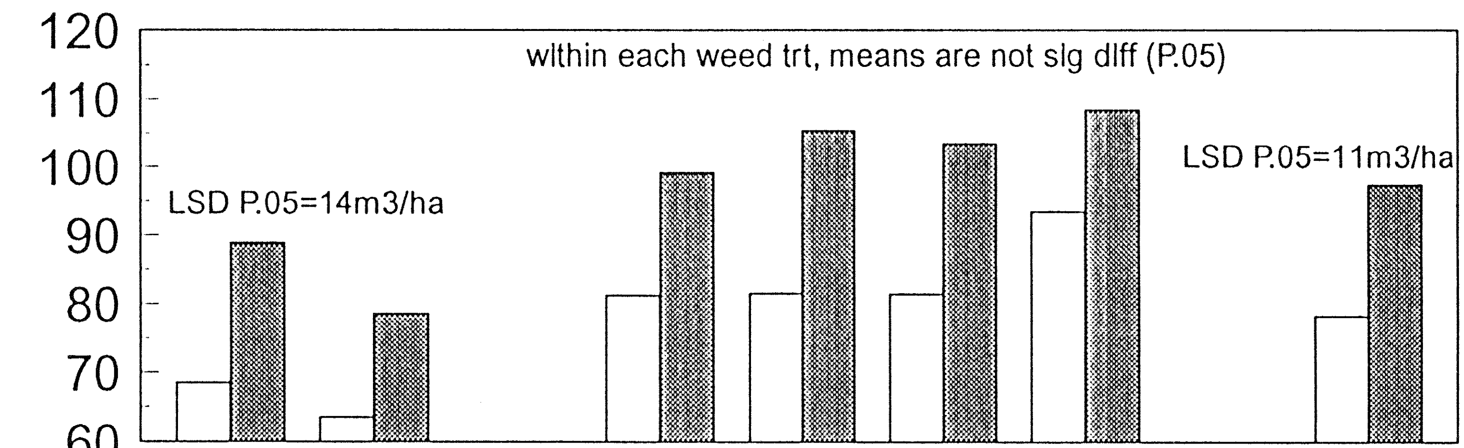
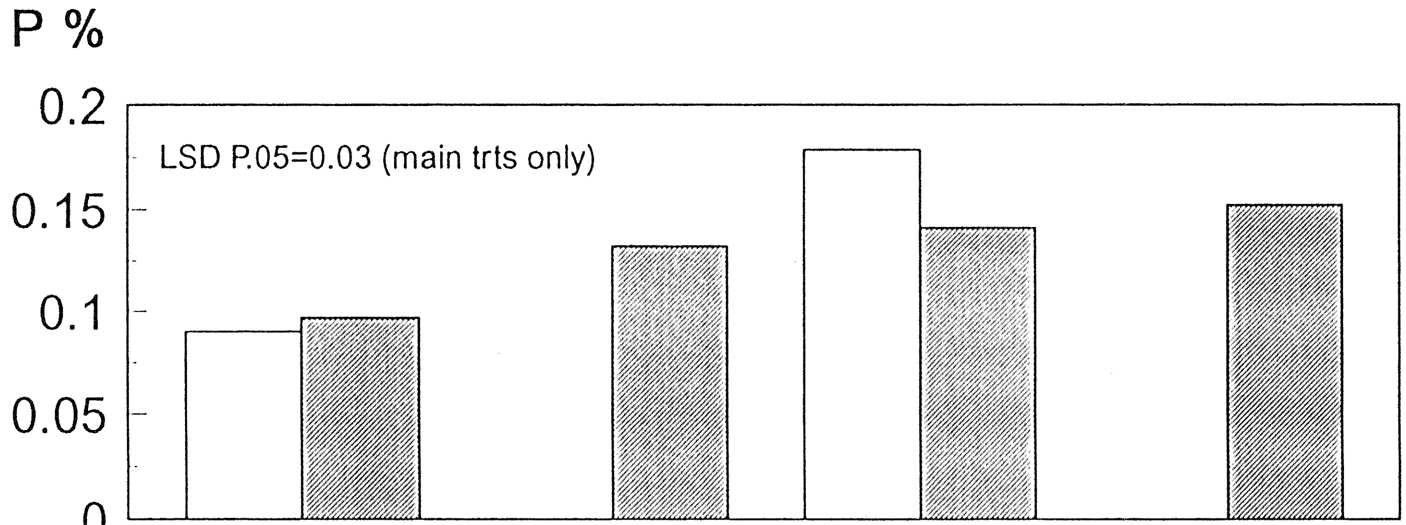
Figure 1. The effect of weed control, nitrogen, phosphorus and magnesium fertilising on volume (m3/ha) after 4 years



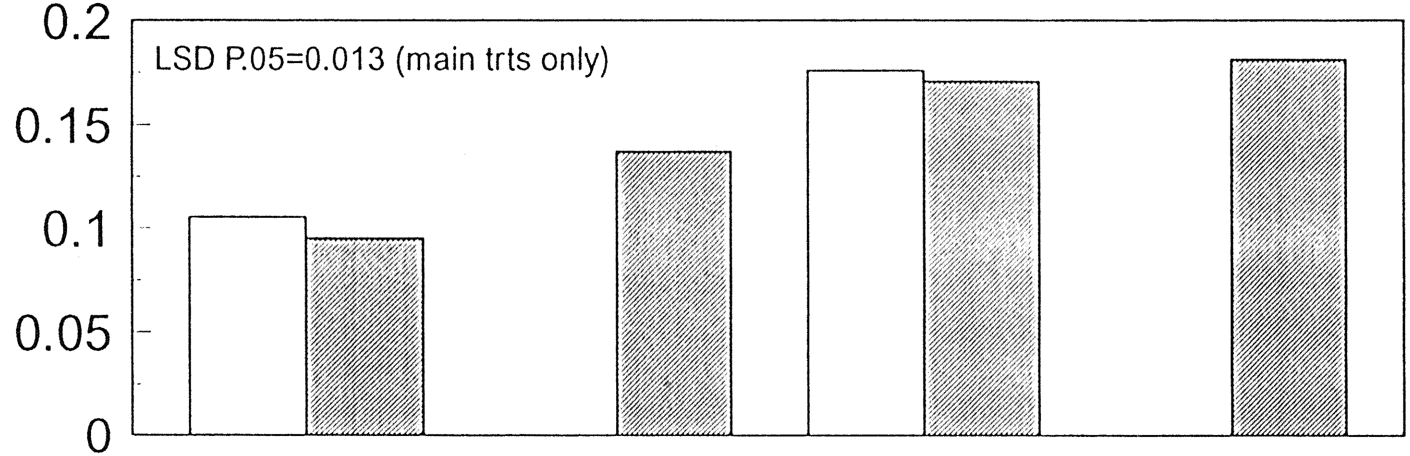
Treatment	no fert	N alone		PB	NP0.5B	NPB	NPBMg		Weeds
weeds pres ☐	68.50	63.50		81.20	81.50	81.40	93.40		78.25
weeds abs ▩	88.90	78.60		99.10	105.40	103.40	108.40		97.30

Figure 2. The effect of phosphorus, nitrogen and magnesium on foliar P concentrations after one year



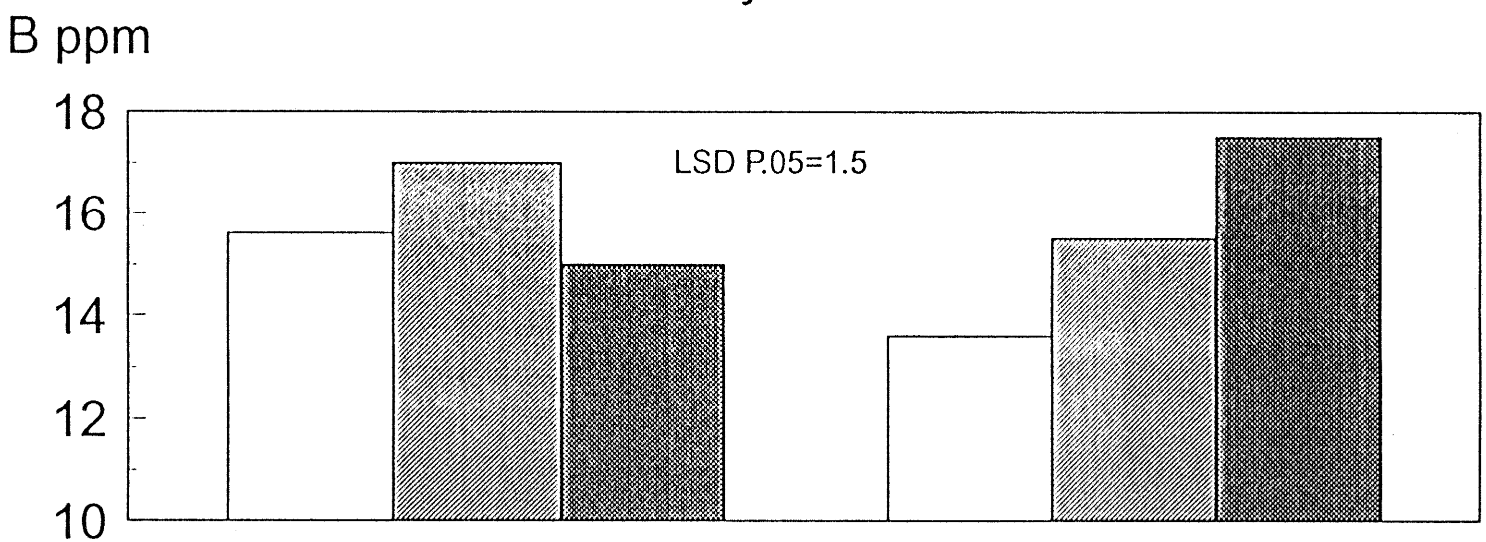
Treatment	control	50 kg P	100 kg P	100 P + Mg
No N	0.0900		0.1790	
With N	0.0970	0.1320	0.1412	0.1525

Figure 3. The effect of phosphorus, nitrogen and magnesium on foliar P concentrations after four years



Treatment	control	50 kg P	100 kg P	100 P + Mg
No N	0.1050		0.1760	
With N	0.0950	0.1370	0.1710	0.1815

Figure 4. The effect of treatment (varying P and Mg fertiliser) on foliar B concentrations after 4 years



	no weeds	weeds
NPB	15.6	13.6
NBhalfP	17.0	15.5
NPBMg	15.0	17.5